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PLANNING AND PROGRAMMING OF WORKS

Application of

THE LINE OF BALANCE TECHNOLOGY

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EE ON PLAN PROJECTS
New Delhi
December, 1960

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FOREWORD

A first reaction to the term "Line of Balance" might be one of skepticism. It might seem rather a complicated and esoteric concept from its nomenclature.

We have taken the courage to introduce it all the same.

We hope that greater familiarity with its many uses in modern management will break down resistance to this strange terminology.

Though the nomenclature is unfamiliar, the concept is significant. In effect the technique is utilised to interlink time, tasks, control elements and utilisation of capital resources by means of work study and graphic presentation. All these are balanced simultaneously, hence the name "Line of Balance".

We will commend that the pamphlet be read. If however the terminology is forbidding, please do not keep on your shelf. Kindly pass on to others. Someone is bound to shake off resistance to mere words and discover the significance and utility of the technique.

We have borrowed a lot from the U.S. Navy, where it has been used to good effect, including the unfamiliar nomenclature.

INDARJIT SINGH,
Secretary,
Committee on Plan Projects.

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COMMITTEE ON PLAN PROJECTS

BUILDINGS PROJECTS TEAM

SUBJECT.—*Planning and Programming of Works-Application of Line of Balance Technology.*

The element of construction in the Second Plan is of the order of Rs. 2,000 crores. In the Third Plan, it is expected to be much bigger. While embarking on a construction activity so big in magnitude and so diversified in character, one has naturally to think about the ways and means of controlling expenditure on various items so that the money spent at any time is commensurate with the benefits received. Planning and Programming of projects therefore has an added significance in the context of the Five Year Plan.

2. The importance of planning and programming has been recognised in production processes. Today the management stresses "more units of production of the highest quality at the lowest possible cost at the time consumers demand." It is only through the medium of sound and effective production planning, programming and control that this objective can be reached. Modern production has become more complex requiring more scientific methods of control and analysis of the manufacturing methods in advance.

3. The top management must have an effective means of coordinating the various phases of operation. Similarly, the various executive levels must know whether or not materials will be delivered in time or if not, how late. They should be able to foresee the shortcomings and predict future inadequacies, so that necessary steps could be taken to "short circuit them or minimise their effects". Decisions on such vital issues require the knowledge of whether or not current progress of individual constituents is "in phase" with the schedule of completion.

4. Several methods have been proposed for efficient programming and control of production processes. One recent tool in the hands of the planning engineer is the Line of Balance Technology which essentially is a technique of "assembling, selecting, interpreting and presenting in graphic form, the essential factors involved in a production process from raw materials to the completion of end product against a background of time." The technique is highly effective in determining areas of weakness and focusing the attention of the administrator or the executive on items requiring immediate attention. So far this techniuqe has been used with telling results in industries and it has got immense potentialities for application in other fields as well.

5. The construction programmes envisaged in the Plan are not much different from any production process. The end products as well as the time and rate of delivery are fixed. A successful working out of such a plan requires all the skill and ingenuity necessary for production processes. The principles of planning and programming are also quite similar. But so far little or no attention has been paid to this, either for want of time or non-availability of proper technique. As a result, the time element for the completion of a project is not fixed in a scientific or rational way. Projects get delayed due to action not being taken on some constituent elements at proper time. Such delay in turn leads to idle investment on certain constituents ahead of utility. Further, in the absence of scientific programming, it becomes difficult to have a correct quantitative and qualitative appraisal of the situation in regard to several elements constituting a project or projects. Consequently, it is not possible to re-appropriate available finances at the proper time for other items where it can be efficiently utilised within the specified time.

6. The draft outline of the Third Plan correctly lays emphasis on the phasing of projects and outlays as without this "it will not be possible to implement the Plan efficiently, to keep investments in harmony with the internal and external resources available from year to year and to ensure each stage of the Plan a series of projects under execution, so that there will be continuity both in planning and in the flow of benefits." This objective can be achieved only if systematic planning and programming are undertaken for works individually and collectively and for the Plan as a whole. The Line of Balance Technology will stand in good stead in achieving this objective. On the basis of the detailed study of a number of projects taken up in the Second Plan, the Committee on Plan Projects has attempted to apply this technique for a few representative projects.

7. The projects taken up for study are—

(a) Construction of 50 pre-fabricated school buildings.

(b) Construction of grain storage structures.

(c) Construction of a bridge.

(d) Sewerage and sewage disposal scheme for a town.

The charts with regard to these are given in plates 2 to 5 appended to this note. Plate 1 gives the application of this technique to a simple production process.

8. The L.O.B. study comprises ~~of~~ the following 4 steps listed in the sequence in which each is developed.

(1) The objective.

(2) The programme-production or construction plan.

(3) Programme progress which indicates the status of performance at a particular point of time.

(4) The line of balance which gives a visual comparison of the progress with the objective in view.

9. *The Objective.*—The first step is to determine and set down the objective which may be the delivery schedule of the end item or items in view. In plates 1, 2 & 3 where the end product is a number of identical items the objective chart is set out by plotting the number of end items to be delivered at different intervals of time. For example, in plate 2, 15 pre-fabricated schools are to be delivered at the end of 6 months, 15 more at the end of 9 months and so on.

10. Plates 4 and 5 are illustrative of projects with single end products such as the construction of a bridge or completion of a sewage disposal scheme. In this case the objective chart has to be set out either in terms of the extent of physical completion or expenditure incurred with reference to time. The chart naturally may or may not be a straight line though it has been shown as a straight line in plate 4. It may be more ideal to have it as depicted in plate 5. But this may not be of much sifinificance as the line of balance depends to a great extent on the objective graphs of individual components of the end item. The compilation of these graphs is based on the lead-time for the various components which is described in the succeeding paragraphs.

Programme

11. The second step is the determination and setting down of the programme. The programme as used here is the planned process of production or construction. The construction of the programme chart in terms of key operations and their lead-time relationship to final completion is the most vital stage in the line of balance study. The plan should cover all the operations from initiation of work through the assembly portion or construction processes to the point of delivery or completion. In a production process, an observation tour has to be made to observe the physical lay out of the plant processes involved and the sequence of operations. The trip should be made 'in-reverse beginning at the delivery end and ending at the point of raw material intake. For a construction programme, a similar in-reverse study has to be made by experienced construction engineers tabulating all the contributing steps and the time at which action on each has got to be taken prior to the fixed date of completion. The number of steps that are encountered will differ from project to project and also from the points of view of examination. If the chart has to be viewed by a top level administrator, the number of points in the chart may be minimum consistent with what is necessary to be known at that level. In the top executive level some additional points may have to be taken up while at the lower level many more minor points may creep in.

12. The criterion of selecting "control points" is not so much their financial implication but their limiting or halting influence on the programme as a whole. To explain this point, we may cite the example of sewage pumps for a sewerage scheme, the cost of which may not be significant compared to the cost of the whole programme but it has an important bearing on the successful completion of the project, as without that the project, even though completed in all respects, cannot be put into commission.

13. After selecting the points, the 'lead-time' has to be calculated in a realistic way. Determination of the points to be monitored and the establishment of the proper lead-time for each require comprehensive understanding of the construction process. With more number of control points, the 'sensitivity' of the programme is enhanced. But this makes the programming more complicated and involved. The usefulness of the entire study depends on the quality of this programme which can therefore be considered as the 'heart' of the whole technique.

14. Allied to the lead-time is the extent of time coverage for each constituent item. To illustrate this point, we can turn to plate 4 where the 'time coverage' for cement is more than that for high tensile steel even though the lead-time for both is the same. This is because of the fact that the production process dictates that the supply of high tensile steel has to be covered within a shorter range of time while that of cement can be over a longer range. This incidentally helps in budgeting for materials and ordering out their supplies according to a phased programme.

15. The construction of the objective curve for individual items of single-end-item projects follows, as mentioned earlier, from the programme chart and the extent of time coverage for each item. In plate 4 item No. 4 which is "manufacture and supply of steel bearing" has a lead-time of 24 months and a time coverage of 16 months. The objective graph for this therefore should start from the origin and cut the completion level line at the end of 16 months. Item No. 17 which is "collection of material for approaches" has a lead-time of 9 months and a time coverage of 6 months. This means that this item of work should be taken up in hand 15 months after the start of work and completed within another six months. The objective graph therefore will start from the abscissa at the 15th month and merge with the completion level line at the end of 21 months from the start of work. Strictly speaking the objective curve of individual items should be parallel to the objective curve of the item as a whole if the required rate of availability for an element of the end item is the same as that of the completed item itself but generally this is not found to be so. The objective curve of each item may lead or lag the curve for the item as a whole at varying degrees of divergency as can be seen from chart 4.

16. The reckoning of time along the abscissa may be in terms of months, fortnights, weeks or even days according to the time of completion of projects and the accuracy with which the graphs are to be drawn. For easy interpretation, the programme chart can be coded by symbol, colour and number to indicate the type of operations performed at each control point. The numbering should be serially done starting from the top left hand corner. This will result in a number of "sequential phases" such as the final assembly phase, major sub-assembly work, other contributory works etc.

Programme progress

17. In the two steps explained above, we have developed—

(1) A graphic presentation of the objective; and

(2) A pictorial presentation of the planned manufacture or construction process with a view to achieving the objective as contemplated.

The next step in this study is the development of the progress chart which aims at giving at a glance the actual performance on various constituent items at a given time.

18. The construction or production progress is usually depicted in terms of units of end items. In single end item projects, the progress is depicted as a percentage of each constituent element. The information for compiling this is obtained principally from a physical inventory for each control point, which can be obtained through progress reports and/or through physical verification.

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19. In big construction programmes it will not be unusual to find control points, which represent a group of operations or supply of different categories of the same material. A case in point is the supply of steel bars which will comprise ~~of~~ different diameters according to the requirements. The progress chart should show the status of the least available material of the group but the bar for this control point can be extended upward to indicate the status of the group as a whole but left uncoloured. Such bars are normally called "ghost bars". On plate 4, such a bar is indicated for control point No. 11 which is the "supply of steel". The status with regard to this control point *i.e.* supply of steel viewed as one unit is different from that for steel of small diameter alone. The position with regard to steel of small diameter is coloured while the remaining is left uncoloured which indicates that though the status of the control point will appear to be satisfactory, it is not really so as without the accumulation of necessary amount of steel bars of small diameter the work cannot proceed harmoniously.

20. In drawing these bars it may be advantageous to use different colours for various control points and stick to the same colour for the same control point, both in the programme and progress chart. This will facilitate easy identification.

The Line of Balance

21. Now we come to the striking of the Line of Balance which is the pivotal centre of the study. With the setting up of the objective graph, the programme and progress charts, the accumulation and display of physical information is complete. The next task is the proper correlation of the intelligence so collected and displayed. This is accomplished by striking a line of balance which is the basis for comparing the progress with the objective.

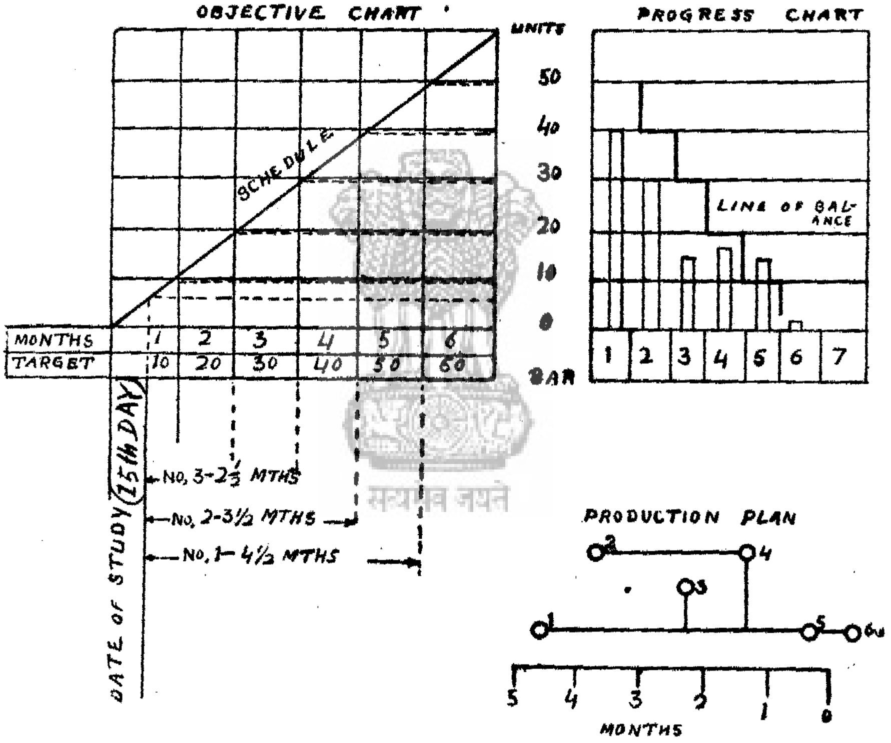
22. The line of balance has to be struck for a particular point of time. The balance line quantity for each control point depicts what should be available at that point in terms of the end products on the date of study, *to be in phase with the delivery schedule.*

23. The steps in striking of the line of balance are indicated below :

(a) Plotting the balance amount for each control point. This is done by starting with the study date on the horizontal axis of the cumulative delivery (objective) graph, mark off to the right the number of days, weeks or months of the lead time for that control point, draw a vertical line from that point on horizontal axis to the cumulative delivery schedule. From that point, a horizontal line is drawn to the corresponding bar on the progress chart which will represent the balance quantity for that bar.

(b) The horizontal balance line of all bars are connected to form a staircase pattern across the progress chart. A general sketch to illustrate the procedure is given overleaf.

STRIKING THE LINE OF BALANCE



24. For single end item projects, the line of balance can be struck not from the objective curve of the item as a whole but from the objective curves of the individual elements constituting the end item. The balance quantity of an individual item in that case will be the intercept of its objective curve with a vertical line drawn at the point of study. This in turn is projected on to the corresponding bar of the progress chart and the individual balance line so drawn joined to form the line of balance. In such a case the balance line will not necessarily be of a continually descending type, from left to right as in the case of repetitive end item projects. The line of balance on plates 4 & 5 illustrates the principle.

Interpretation of the line of balance

25. The next step is the interpretation of the chart and the critical evaluation of the production or construction situation as depicted by the various elements of the chart. Some of the observations from such a study may be plain and obvious while others though necessarily not so obvious may be of fundamental value. The primary purpose of the chart is to find out whether the progress is in phase with the objective or not. The bars which are below the balance line are the elements which require immediate attention. The shortfall in each case can be qualitatively and quantitatively assessed so that the management can take adequate steps to remedy the situation or adjust the work on other elements, in such a way as to avoid idle investment. On the other hand, the bars which reach much above the balance level indicate the pattern of investment which warrants a judicial check. In certain cases extra investment may be necessary either due to uncertainty of availability of some items or the pattern of development which may have to be of a continuing type. In either case, the management can take a *conscious view* of the situation. In certain other cases additional investment may be of no value. The investment in such a case has to lie idle which in the context of an overall programme and control of expenditure is not desirable. The management in such cases can either stop further accumulation at that control point or divert stocks to more profitable use elsewhere.

26. The balance chart on the whole gives the pattern of imbalance of the various constituent elements in pictorial way capable of qualitative and quantitative assessment at all control points which cannot be obtained by any other means. Such a pictorial view will enable the management to take corrective steps *in time* to restore the balance or readjust the objective itself. A reorientation of the objective is shown in Plate 2. The original objective line is incapable of achievement because of inherent difficulty in the procurement of certain constituent elements. A redrawing of the objective line, therefore, becomes imperative and this can be done logically and in a more realistic way from a line of balance study.

27. There are certain other valuable informations that can be derived from the actual delivery curve and the planned delivery curve. The comparison of the slopes of the two curves will indicate whether the current lead or lag at various control points may be expected to continue or not. Horizontal differences at any control point between the curves indicate the lag or lead in terms of time while the vertical difference indicates lead or lag in terms of completed units.

Extension of the principle

28. The line of balance so far we have discussed has been drawn for a particular point of time. We can extend the principle and draw the line of balance even before the starting of work for different points of time as has been done in Plate 2. The line of balance for different points of time will be of staircase pattern with the right hand end sharply rising until the line of balance becomes a straight line parallel to the abscissa at the stipulated period of completion. A study of this chart will indicate the rate of performance which should be achieved at any control point. As an example, the different lines of balance applied to bar 4 of Plate II indicates the rate at which the cement has to be procured. In the case of materials which are not scarce, a knowledge of the rate of supply will preclude idle investment and will enable the executive at site to plan the procurement in a logically phased manner.

29. In the absence of such technique and study, one is apt to overspend on items which are easily procurable, with a view to incurring expenditure and monetary progress. On a little reflection, it will be clear that there is no progress at all in the real sense of the term excepting accumulation of some material ahead of its use. Locking up of capital in such a way is injurious to the successful implementation of the programme especially when the finances available do not match the demands of the situation. Such lopsided planning and execution brings out a bigger gap between the commitment of expenditure and the realisation of physical assets. The line of balance technique applied to the projects as a whole and the individual schemes comprising them will help avoiding such difficult situations.

30. Another intrinsic value of the study is that it enables orderly thinking on the part of the project officials and the management of the various controlling steps and their logical sequence in time and causation. It is difficult in such an analysis to overlook any item of importance.

31. Yet another advantage of this technique is that it enables the different levels of administration to view the project on a common basis. The line of balance chart as explained earlier can be constructed for the use of an administrator, the top executive or the lower executive. The basis of construction is the same but the points of consideration may be

different to suit the different ~~view points.~~ responsibilities It is needless to emphasise the necessity for such coordinated view of the projects at different levels if the programmes, so vast in magnitude and varied in character as envisaged in the Five Year Plans, are to be successfully implemented.

The technique of line of balance study is after all quite simple. But its effectiveness in surveying a wide range of programme is of great value in that a coordinated picture is obtained of all important factors needed for a critical evaluation of schemes and for a correct appreciation of the achievements and set-backs. The principle of the technique is a broad-based one and can bear effective application on any type of project whether it is setting up of seed multiplication farms, construction of facilities, such as schools and hospitals, or the administration of a training programme. The utility of the study is further enhanced by the fact that it can be applied with equal advantage to projects with single end item, multiple end items and varied end items.

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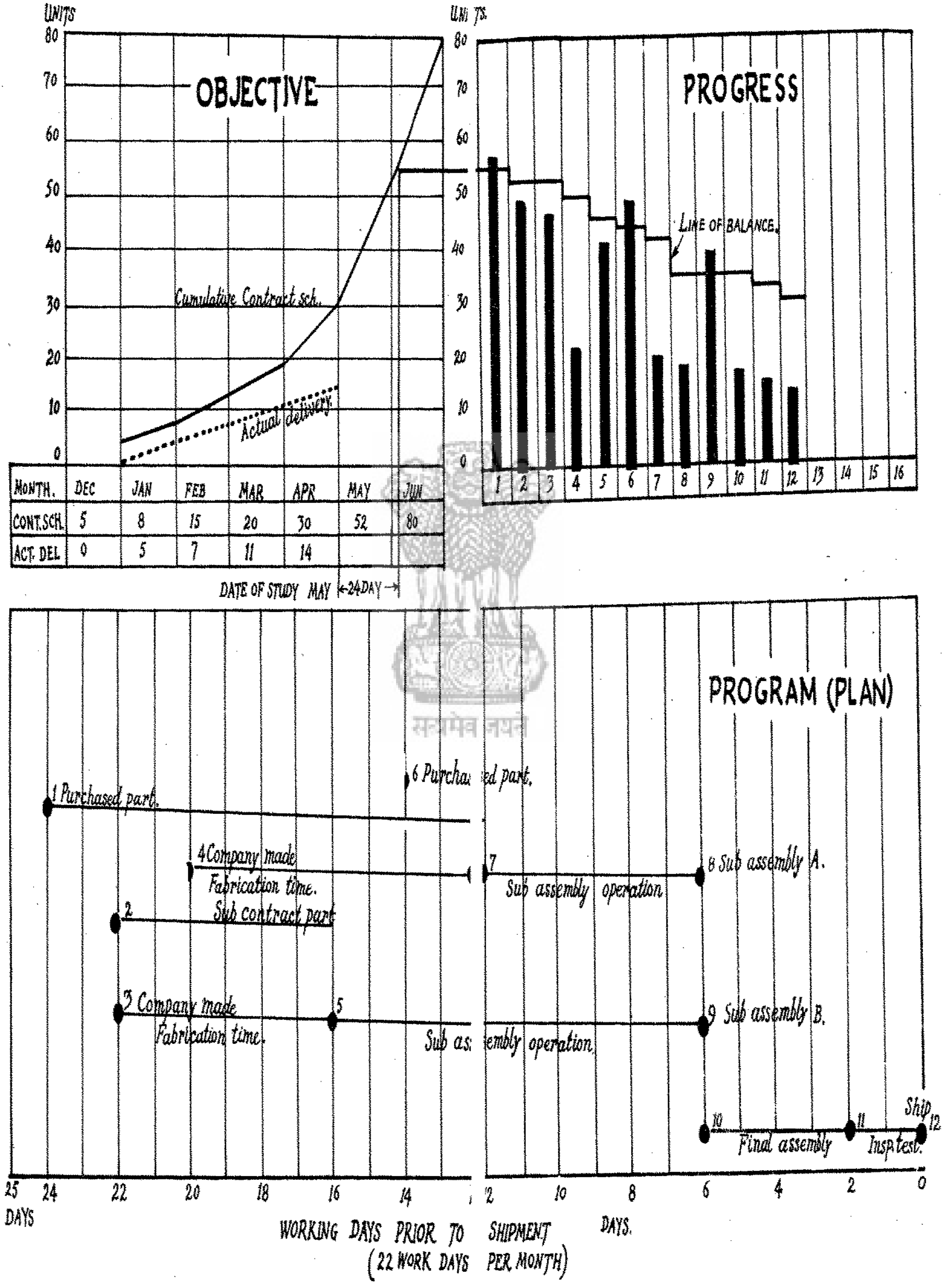
PRODUCTION - PROTOTYPE

PLATE. 1.



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CONT. SCH.	5	8	15	20	30	52	80
ACT. DEL	0	5	7	11	14		

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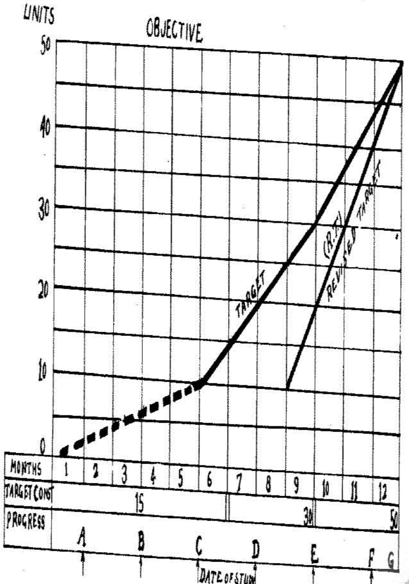
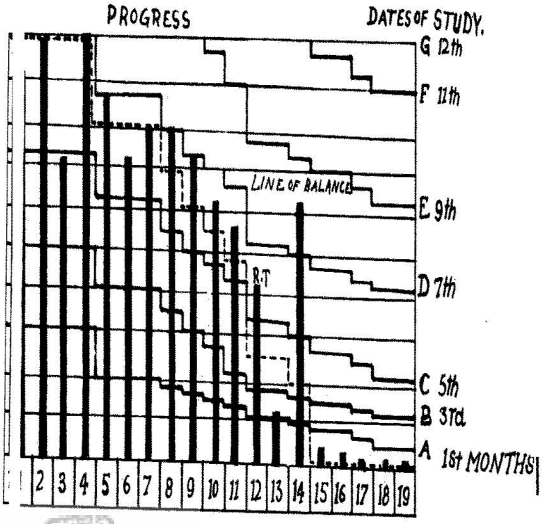
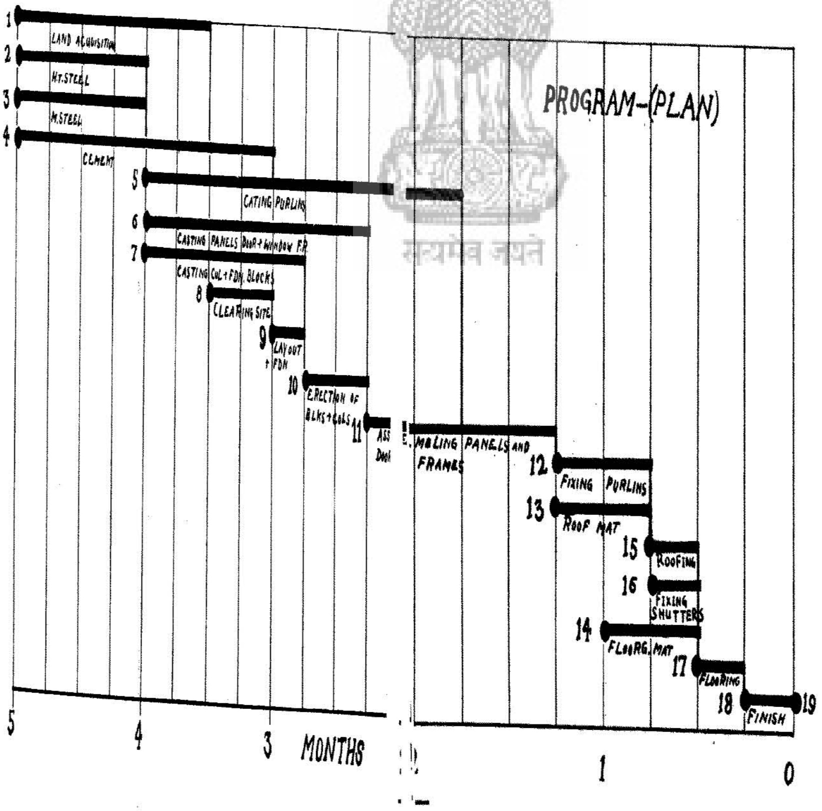
SCHOOLS

PLATE II(



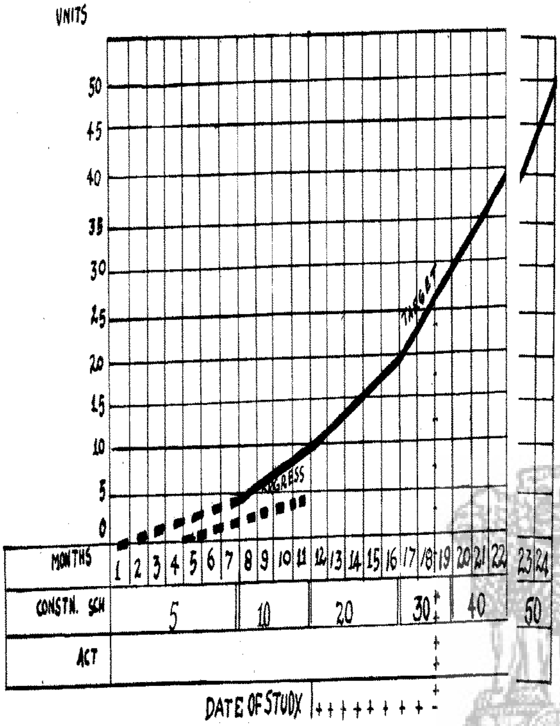




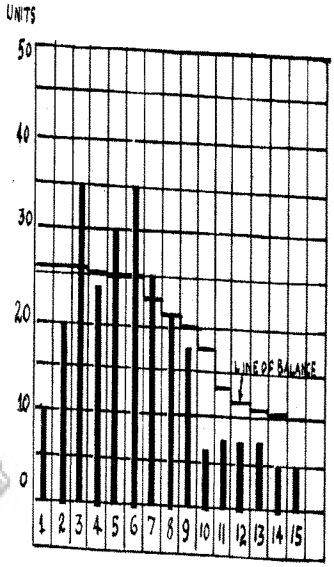
GODOWNS

PLATE III(3)

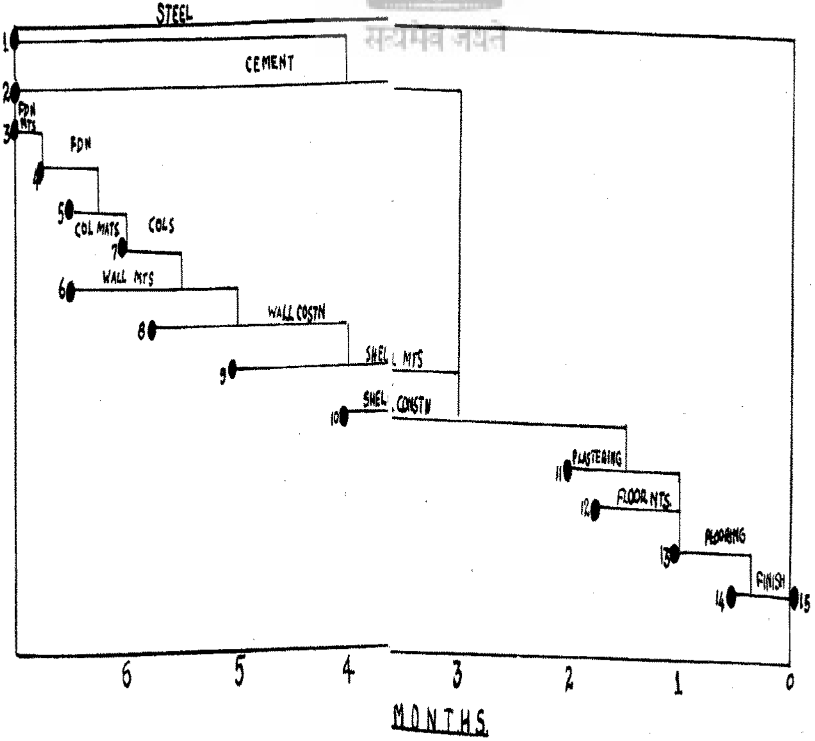
OBJECTIVE



PROGRESS



PROGRAM - (PLAN)



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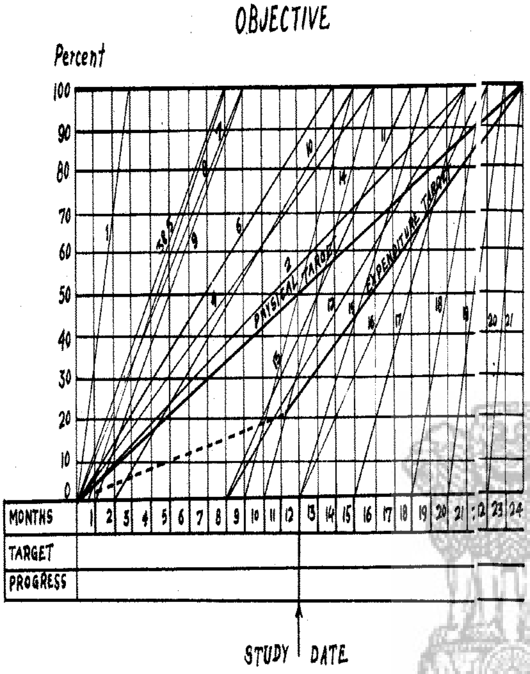
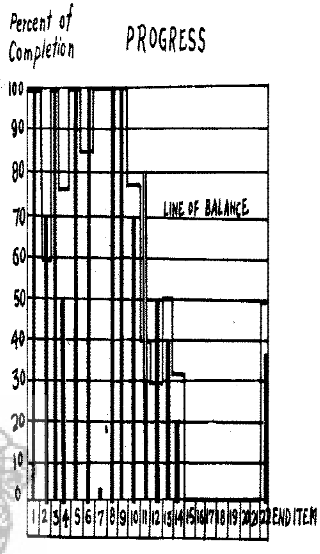
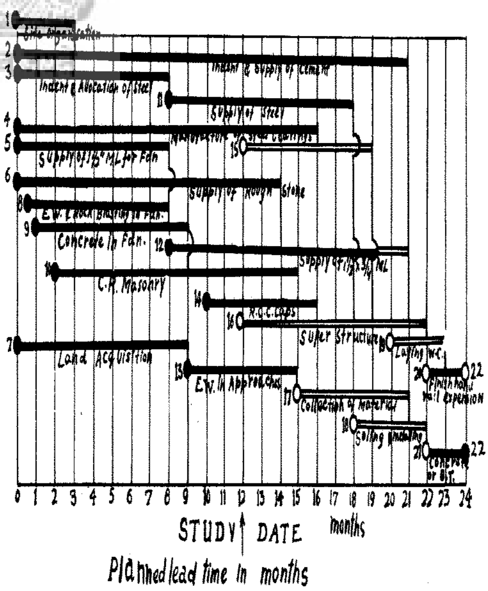
CONSTRUCTION OF A BRIDGE- PROTOTYPE

PLATE- IV(4)

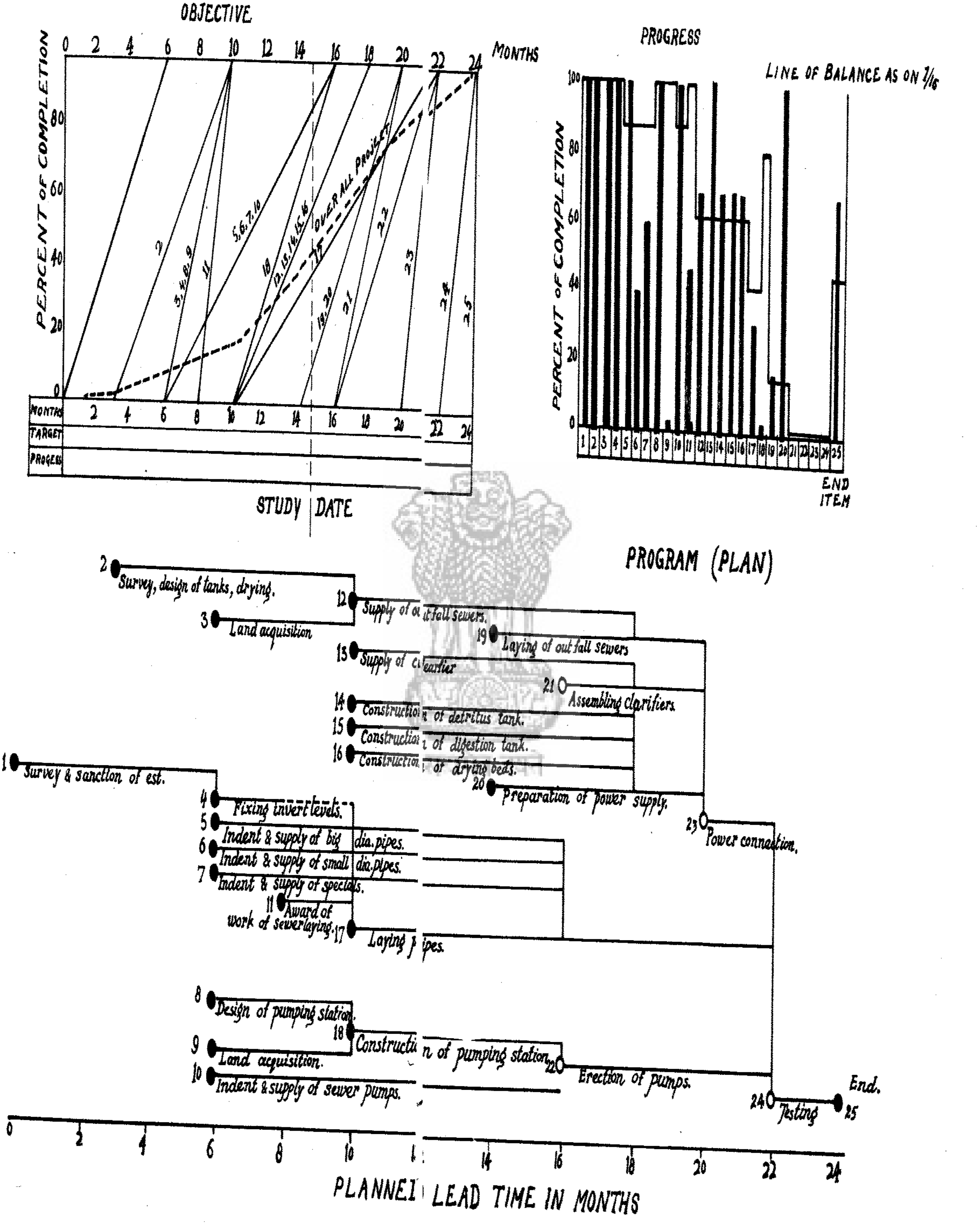






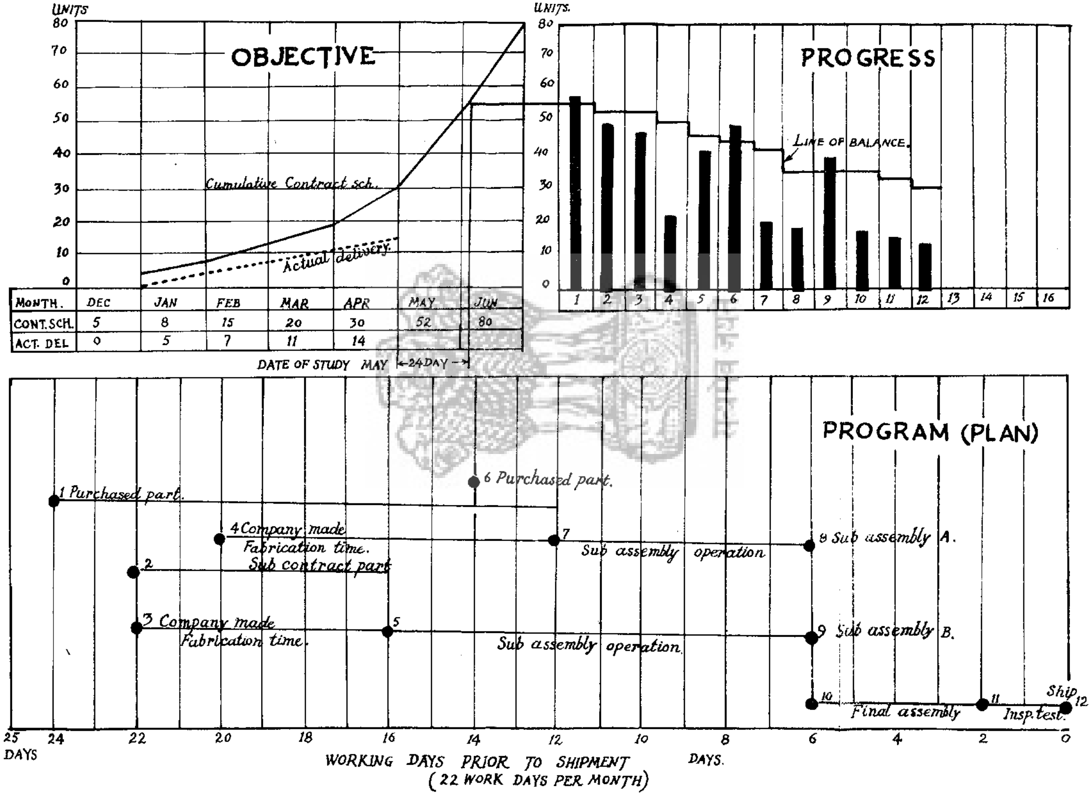
Sewage Disposal Scheme For a Township.

PLATE V.(5)



PRODUCTION - PROTOTYPE

PLATE. 1.



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CONT. SCH.	5	8	15	20	30	52	80
ACT. DEL	0	5	7	11	14		

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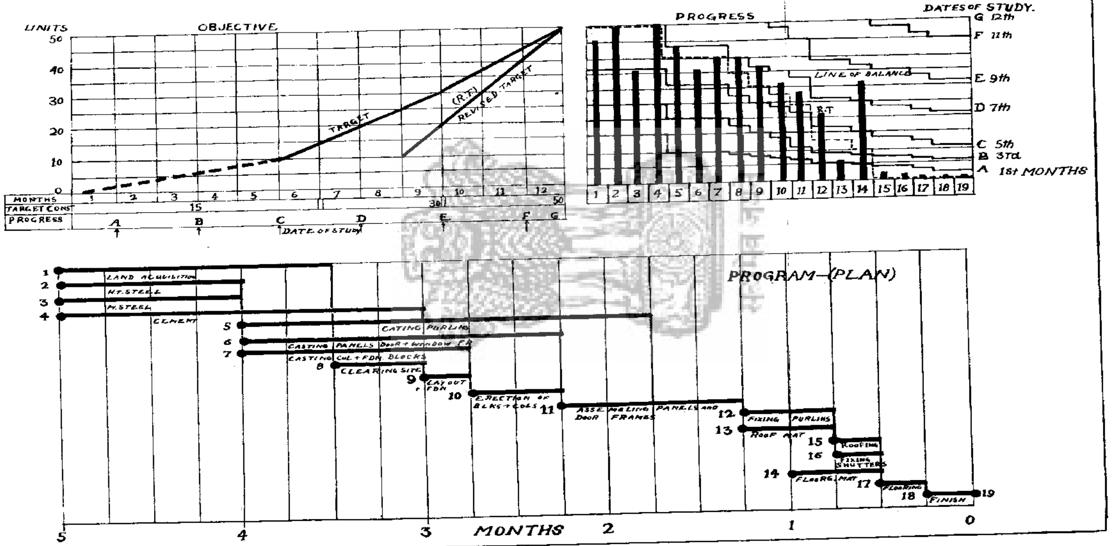
PLATE II(2)

SCHOOLS



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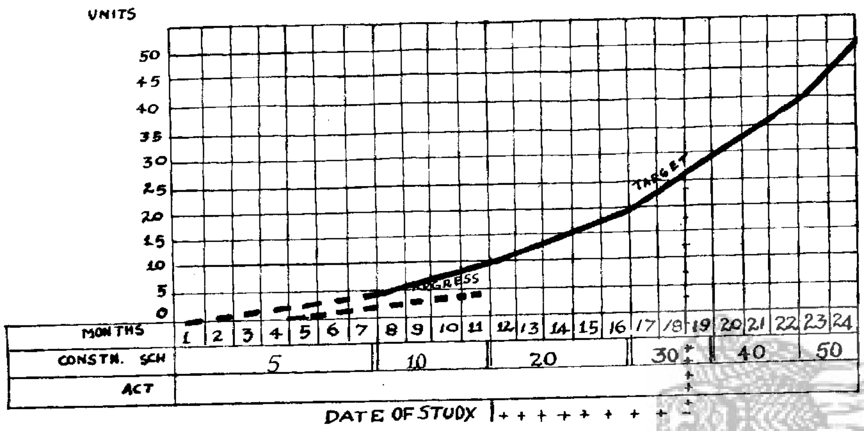
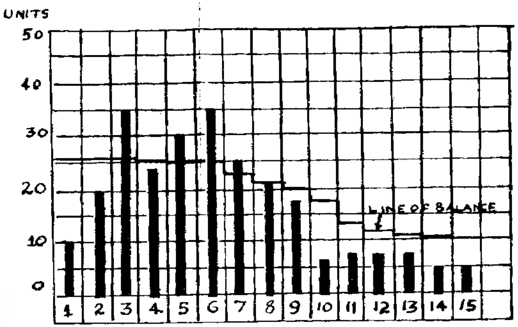
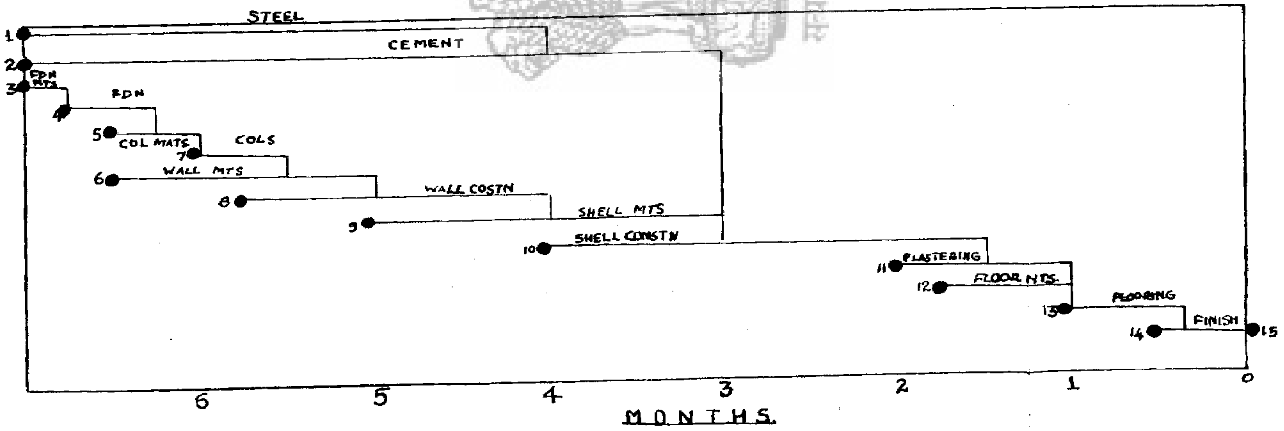
GODOWNS

PLATE II(3)


OBJECTIVE


PROGRESS

PROGRAM – (PLAN)



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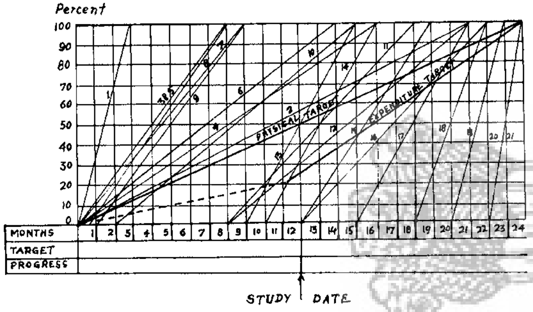
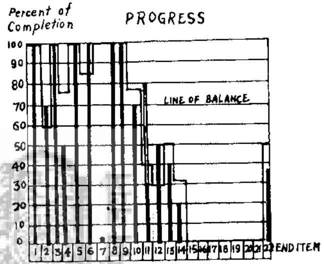
CONSTRUCTION OF A BRIDGE— PROTOTYPE

PLATE-IV(4)

OBJECTIVE



PROGRESS



PLAN